

Detailed Description of Limited Recycle and Full Recycle

The staff expects DOE to consider two approaches for its spent fuel recycling program that would achieve the goal of effectively increasing the utilization of repository space in a proliferation-resistant manner. The first approach would involve (1) an advanced separations step (based on the UREX+ technology, which mitigates the disadvantages of the more common PUREX process¹) and (2) a limited recycle of mixed-oxide (MOX) fuel in conventional LWRs and/or Advanced Burner Reactors (ABRs) such as a liquid metal fast flux reactor. The second approach would involve full recycle beyond these two primary steps, using ABRs to close the fuel cycle and transmute the transuranic waste streams. A process flow diagram for the stages included in limited and full recycling and the fate of the products separated from the spent nuclear fuel is included in Enclosure 2. A summary of the processes involved is discussed below.

Limited Recycle

The primary stages of limited recycling include spent fuel reprocessing and limited recycle in existing LWRs. The UREX+ technology is a refined solvent extraction technology that allows the separation and subsequent handling of several highly pure product streams: (1) uranium, which can be stored for future use or disposed of as low-level waste, (2) a mixture of plutonium and neptunium, which can be reused as MOX fuel, (3) separated fission products that would eventually require long-term storage and disposal, and (4) the transuranic elements americium and curium. Several of the processes associated with the UREX+ technology are discussed further in the next section (on full recycle).

The performance goals of the UREX+ process are to achieve the following:

- Purity levels of uranium, plutonium, and neptunium sufficient to meet the MOX fuel specifications in ASTM C833-01
- Recovery of the fission products technetium and iodine to levels sufficient to achieve up to a 20-fold decrease in offsite dose, with sufficient separation of fissile actinides to allow future transmutation
- Recovery of the fission products cesium and strontium to a level sufficient to reduce their contribution to the heat load in the repository equal to the heat load of all other fission products and to remove sufficient transuranic content to allow decay storage and ultimate disposal as low-level waste
- The separation of americium and curium to levels that result in a 100-fold reduction of the heat load to the repository
- Produce final raffinate streams containing the rare earths and all soluble fission

¹PUREX stands for plutonium uranium reduction and extraction, and UREX+ stands for uranium reduction and extraction. Both processes use liquid-liquid solvent extraction techniques. The PUREX process separates a stream of plutonium and a stream of uranium from the waste stream containing both transuranics and fission products, while the UREX+ process separates a mixed uranium-plutonium stream from a transuranic stream and fission product streams.

products (except cesium, strontium, technetium and iodine), which can then be converted into a solid form for final disposal in the repository

The advantages of the UREX+ process over the PUREX process are the potential for significant cost reductions, the elimination of the need for waste tank farms, and the ability to separate and manage very pure product streams of key elemental and isotopic constituents.

The fuel stream, comprising uranium, plutonium, and neptunium, accounts for about 94% of the total spent fuel mass and 15% of the initial and 70% of the long-term repository heat load. The transuranic elements account for less than 1% of the total mass and 20% of the initial and 30% of the long-term heat loads. The fission products make up 5% of the mass and 65% of the initial and negligible long-term heat loads.

As shown on the process flowchart in Enclosure 2, the resulting streams from the UREX+ process follow several different paths. In addition to the UREX+ facility, a new fuel fabrication facility would need to be built to handle the uranium and the mixed plutonium/neptunium UREX+ output streams. The output from the new fuel fabrication facility would be recycled as MOX fuel, resulting in the limited recycle of the spent fuel.

Some of the benefits of limited recycling would depend on when the material is recycled. For example, recycling spent fuel within the first several years of removal from the reactor would significantly limit the buildup of americium-241 from plutonium-241 decay. Limiting the buildup of americium-241 is desirable because the isotope's energetic alpha decay and relatively short half-life result in a high heat output. The presence of plutonium-241 in the spent fuel, however, would require greater shielding in the limited recycling facilities than americium-241. As shown on the process flowchart in Enclosure 2, recycling the uranium, neptunium, and plutonium stream has the potential to reduce the long-term repository heat load by 70 percent.

Interim storage may be needed for several of the UREX+ output streams, especially the transuranic elements americium and curium. The length of time the interim storage phase would need to last before the final processing of the transuranic actinides and fission products is unclear. While it is likely that the storage facility would be co-located with the UREX+ facility, some process streams might be stored at another location. The remaining fission products could be separated into a stream for short-term storage (to reduce the heat load) and a stream for long-term storage in specialized waste forms.

Full Recycle

Full recycling would include the primary stages of limited recycling but would close the fuel cycle loop by using ABRs (and/or possibly linear accelerators) to transmute the fuel constituents into much less hazardous elements and by using pyroprocessing technologies to recycle the fast flux reactor fuel. Full recycle has the potential to significantly reduce proliferation risk by eliminating the buildup of all isotopes.

In addition to the reprocessing and limited recycling of spent fuel, full recycling would involve transmutation of the transuranic elements. Transmutation occurs in the high flux field typically associated with a liquid metal cooled fast flux reactor. DOE currently has two potential technologies from which to choose: the Integral Fast Reactor (IFR), which uses metal fuel, and the Advance Liquid Metal Reactor (ALMR, also known as the GE Power Reactor, Innovative, Small Module [PRISM]), which can use either ceramic fuel or metal fuel.

The IFR system developed by Argonne National Laboratory would use a new type of metal

alloy fuel. This fuel would be recycled using a pyroprocess whereby uranium, plutonium, and other transuranic elements could be separated from the other radioactive waste and reused in new fuel assemblies. The IFR design also has the potential to burn actinides from LWRs. This would require a separate aqueous reprocessing facility to be built (i.e., the UREX+ facility). The remaining waste would have a significantly reduced heat load and volume and would remain a radioactive hazard for only hundreds of years, not for hundreds of thousands of years. As shown on the process flowchart in Enclosure 2, the transuranic elements contribute approximately 30 percent of the long-term repository heat load (integrated over time). With full recycling, most of the transuranic elements would be transmuted and two-thirds of their heat load could be reduced. Therefore, full recycling has the potential to achieve an overall 90 percent reduction in the total long-term repository heat load.

The ALMR would involve much the same fast flux reactor technology as the IFR, however, the primary difference is its ability to use ceramic or metal fuel. DOE may prefer this technology since ceramic fuel is currently more commonly used than metal fuel.

The remaining fission products from the reprocessing of the spent LWR fuel would be separated into streams for short-term storage (heat load reduction), possible transmutation, and long-term storage in specialized waste forms.